

Medial column foot systems: an innovative tool for improving posture

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Introduction

Intuitively we know feet affect posture. Engineers use this concept daily: as goes the foundation (foot), so goes the building (posture). Rothbart describes the foot–posture relationship dynamically, e.g. the impact the walking foot has on posture.

Morton (1932) asserts a short 1st metatarsal (relative to the 2nd and 3rd metatarsals) prevents it from fully participating in weight bearing. While this concept appears correct, it is only a partial explanation of the pathodynamics engaging hyperpronators. Embryologically the foot goes through a series of torsional changes (Streeter 1945, Lash et al. 1997, Aiton et al. 1995, McLachlan et al. 1997, O’Rahilly et al. 1987, Smith 1999, Jirasek & Keith 2001, Gasser 1975, Patten 1946). If these torsions end prematurely (Tabibzadeh & Pettersson 1995), the 1st metatarsal and big toe (proximal phalanx and hallux) remain structurally elevated and inverted (in elevatus) relative to the lesser metatarsals and phalanges (Straus 1927, Olivier 1962). It is this retained elevatus that forces the walking foot into hyperpronation

(Rothbart & Esterbrook 1988, Rothbart & Hansen 1995, Filner 1996, Liley 1996). It is hyperpronation that draws the posture forward (Rothbart et al. 1992, Rothbart & Hansen 1995, Schneider et al. 1995, Filner 1996, Liley 1996). And it is this forward posture and ensuing compensations that lead the patient into chronic pain (Rothbart & Esterbrook 1988, Rothbart et al. 1992, Rothbart & Hansen 1995, Petersen 1995, Schneider 1995, Filner 1996, Liley 1996).

The embryology section briefly outlines [1] the normal ontogenetic stages within the lower limb bud and [2] the abnormal ontogenetic events that result in either the Clubfoot deformity (Cfd) or Rothbart foot structure (RFS). (This paper does not deal with the positional or structural deformations that can occur postnatally, e.g. rearfoot varum from massive trauma to the heel bone, leg length discrepancy from sepsis of the femoral growth plate, etc) Section 2 (RFS, clinical significance of PME) discusses RFS impact on posture and gaiting, and provides a methodology for diagnosing RFS in the adult foot. Section 3 (stabilizing RFS)

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Box 1

- 1.0 Normal embryonic development (weeks 1–8 pf).
- Week 3 post fertilization (pf) lower limb bud appears
 - Week 6 pf limb bud at right angles to rump: soles and posterior surfaces face cephalad (Fig. 4, Right slide, top)
 - Week 8 pf soles and posterior surface face one another (Fig. 4, slide, middle, Fig. 5)
- 1.1 Normal foetal development (weeks 9 pf to full term).
- Week 9 pf primordial ankle and knee joints appear (Fig. 4 Left slide, bottom)
 - Week 10 pf thigh and leg unwinding around longitudinal axis (Fig. 4, Right slide, bottom)
 - Week 11 pf calcaneal supinatus unwinding
 - Week 12 pf talar {head} supinatus unwinding
 - Week 36 pf heel and sole plantargrade to leg
- 1.2 Abnormal foetal development
- 1.21 Talar head fails to unwind: Rothbart foot structure
 - 1.22 Calcaneus fails to unwind: Clubfoot deformity

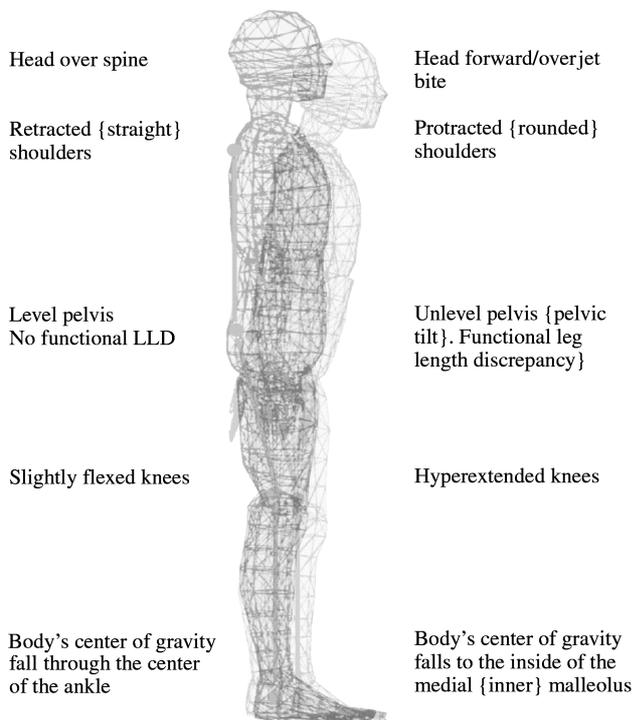


Fig. 1 Deep 1st web space seen in Morton’s foot structure. The 1st web space (space between the 1st and 2nd toes) is more proximal (nearer to the heel) than the 2nd web space.

- Plantar fasciitis
- Chondromalacia
- Sacral iliac joint inflammation
- Sciatica
- Low back pain
- Thoracic outlet syndrome
- Headaches
- Temporal mandibular joint dysfunction

Fig. 2 Chronic pain syndromes associated with Rothbart’s foot structure.

Fig. 3 BioImplosion. Gravity induced skeletal shift. Hyperpronation shifts the body’s center of gravity forward. The axial framework responds by moving out of vertical towards a forward, inward and downward position (typical hyperpronation pattern of left foot > right foot produces the following postural pattern: left PSIS is anterior [forward] and superior [higher] relative to right PSIS, pelvis is unlevelled, left leg is functionally longer than right leg, thoracic cage is rotated counterclockwise, left shoulder is protracted [forward] and superior [higher] relative to right shoulder). Cranial and connective tissue compensations are commonly initiated and/or perpetuated by this forward postural shift which, in turn, can be responsible for many of the chronic pain conditions seen clinically. Adapted and reproduced with permission from the American Journal of Pain Management, 1995.



introduces an innovative foot appliance that [1] reduces static and dynamic hyperpronation and [2] reverses postural shifts generated from RFS.

Embryology

Ontogenetic retention of talar supinatus: the Rothbart foot structure

One thousand and six Egyptian feet are evaluated for talar supinatus (Sewell 1906). Angular variances, up to 20°, are reported. If the talar head fails to unwind (remains in supinatus), the navicular remains relatively supinated (torsionally twisted inward around its longitudinal axis), and with it, the internal cuneiform, 1st metatarsal and big toe (Straus 1927, Olivier 1962). Rothbart terms the retained structural elevation of the 1st metatarsal and big toe: *Primus Metatarsus Elevatus (PME)*; see Fig. 6). PME values are clinically

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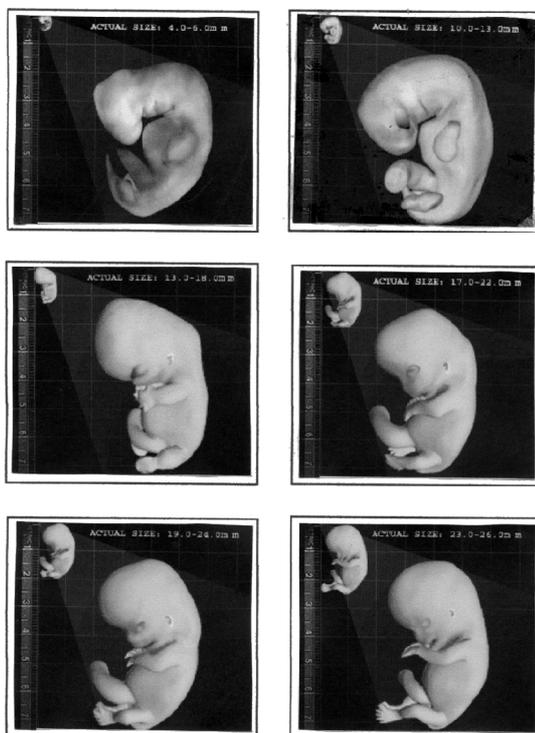


Fig. 4 Left slide, top: Week 3 pf. Limb bud appears as a swelling opposite the lower lumbar. Right slide, top: Week 6 pf. Limb bud sits at right angles to rump of embryo. Soles of feet and posterior compartments of leg and thigh face cephalad. Left slide, middle: Week 8 pf. Limb bud has rotated 90° around its longitudinal axis. Soles and posterior surfaces of thigh and legs now face one another. Right slide, middle: Week 8.5 pf. Primordial toes appear in the developing foetus. Left slide, bottom: Week 9 pf. Primordial ankle and knee joints appear. Right slide, bottom: Week 10 pf. Leg and thigh are unwinding around their longitudinal axes (clockwise left, counterclockwise right) leaving the foot (calcaneus and talus) in supinatus. Adapted and reproduced with permission from Mousework Inc. at WebMaster@visembryo.com.

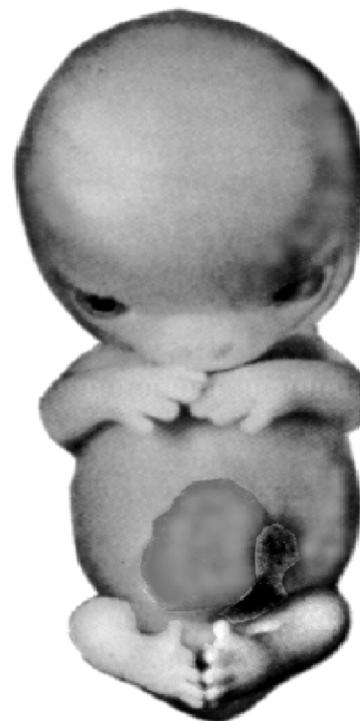


Fig. 5 Frontal view embryo week 8.5 pf. Lower limb bud is rotating 90° around its longitudinal axis (clockwise left, counterclockwise right). Posterior thigh and leg compartments face one another, as do the heels (calcaneal supinatus) and soles (talar supinatus) of the feet. USPTO #6,092,314 Sheet 2, Figure 2. Adapted and reproduced with permission from GRD BioTech Inc., 2000.

quantified using microwedges (Fig. 7).

In the postnatal foot, the navicular articulates with all three cuneiforms. From a structuralist view point, one might conclude that the navicular impacts all three cuneiforms. From an embryological prospective, this is not the case. Straus, Streeter and Olivier depict the unwinding of that talar head, in a linearly sequential and cascading fashion, determines the shape and contour of the navicular, internal cuneiform, 1st metatarsal and big toe. That is, the relative structural position of the 1st metatarsal/big toe is determined by the sculpturing of the talar head. Retention of postnatal talar supinatus results in a

visibly elevated 1st metatarsal/big toe (standing position, subtalar joint neutral).

Ontogenetic retention of calcaneal supinatus: the Clubfoot deformity

If the calcaneus fails to unwind (remains in relative supinatus), the cuboid remains in supinatus, and with it, the lateral two cuneiforms, lesser four metatarsals and accompanying phalanges (Bohn 1929). The footplate unwinds heel to toe (Streeter 1945, 1948, 1951), thus the maxim: *as goes the calcaneus, so goes the talus*. Retention of calcaneal supinatus is always accompanied by

talar supinatus, the Cfd (Bohn 1929).

In the postnatal foot, the calcaneus articulates with the cuboid, which in turn articulates with the navicular, lateral cuneiform and lateral two metatarsals. From a structuralist viewpoint, one might conclude that the calcaneus only impacts these structures. From an embryological prospective, this is not the case. Bohn (1929) describes how the ontogenetic unwinding of the calcaneus affects the lateral column of the embryonic foot. That is, the relative structural position of the cuboid, the lateral two cuneiforms and four lateral metatarsals/phalanges are determined by the sculpturing of the

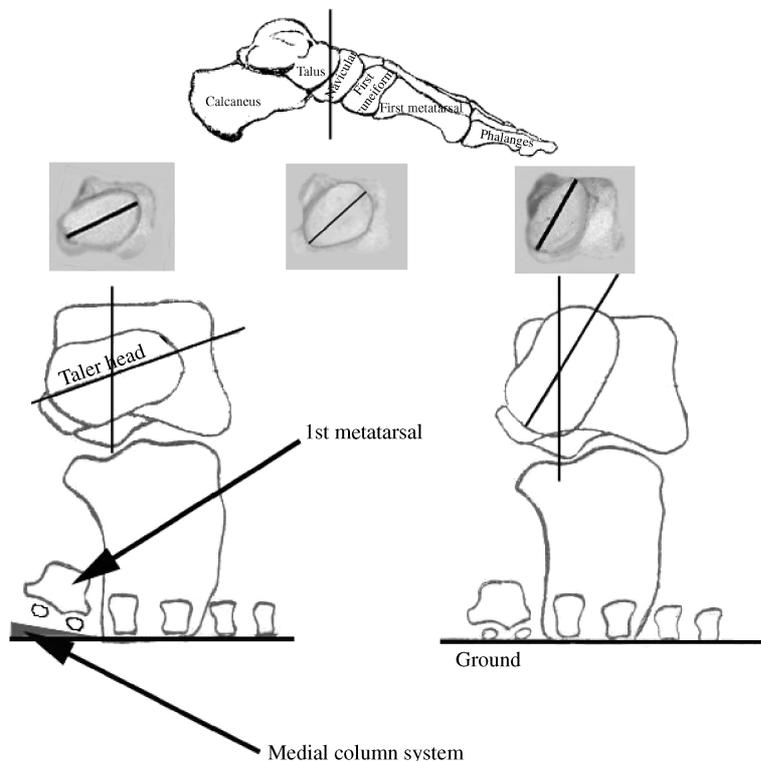


Fig. 6 Talar supinatus, frontal view. Torsional unwinding of the talar supinatus delineated (see upper diagrams, left to right). As the talar head unwinds, primus metatarsus Elevatus is decreased. Lower diagram left illustrates retention of talar supinatus and resulting twist and elevation of the 1st metatarsal (PME) relative to the ground. Lower diagram right illustrated complete unwinding of the talar head and resulting plantargrade position of the 1st metatarsal to the ground. USPTO #6,092,314 Sheet 3, Figure 4. Adapted and reproduced with permission from GRD BioTech Inc., 2000.

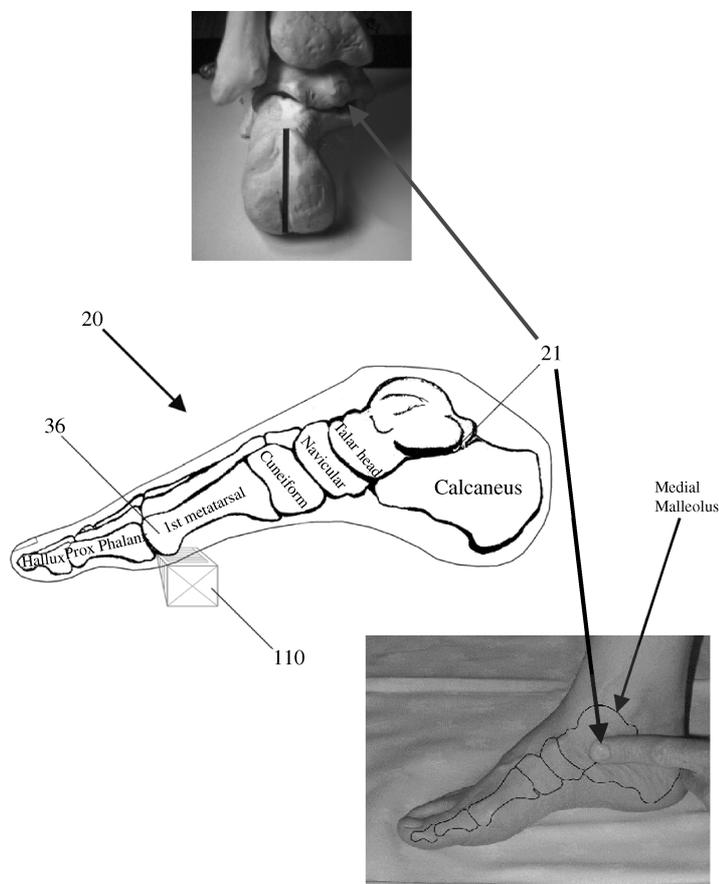
primary ossification site of the talus has already appeared (Sewell, 1906). However, the onset of ossification of the navicular is variable (2.7–4.0 years of age) and late compared to the other tarsal bones (Caffey 1972, Lang 1972, Bardeen 1905, Hoer et al. 1962). The topographical contouring of the inner longitudinal arch (ILA) starts to develop between 12 and 16 months of age. A definite

calcaneus. Retention of calcaneal supinatus in the prenatal foot is manifested as the CfD in the postnatal foot.

RFS: clinical significance of PME

RFS is subtle in the newborn’s foot due to the bulging longitudinal fat pad and incomplete ossification of the tarsal bones. At birth, the

Fig. 7 Measuring PME. With the client standing, locate the subtalar (talocalcaneal) joint (21) as follows: one finger width below and anterior to the medial malleolus (see bottom photograph). Keeping your finger over the subtalar joint space, have your client transfer 90% of their weight to the other foot. With your other hand, slowly guide the foot through pronation (inversion) – supination (eversion) until the margins of the subtalar joint space feel parallel to one another (see top photograph). If the subtalar joint is pronated, the joint space disappears. If the subtalar joint is supinated, the joint space gaps. Slide the microwedge (110) under the ball of the foot (1st metatarsal) until slight resistance is met. Record the PME value off the microwedge.



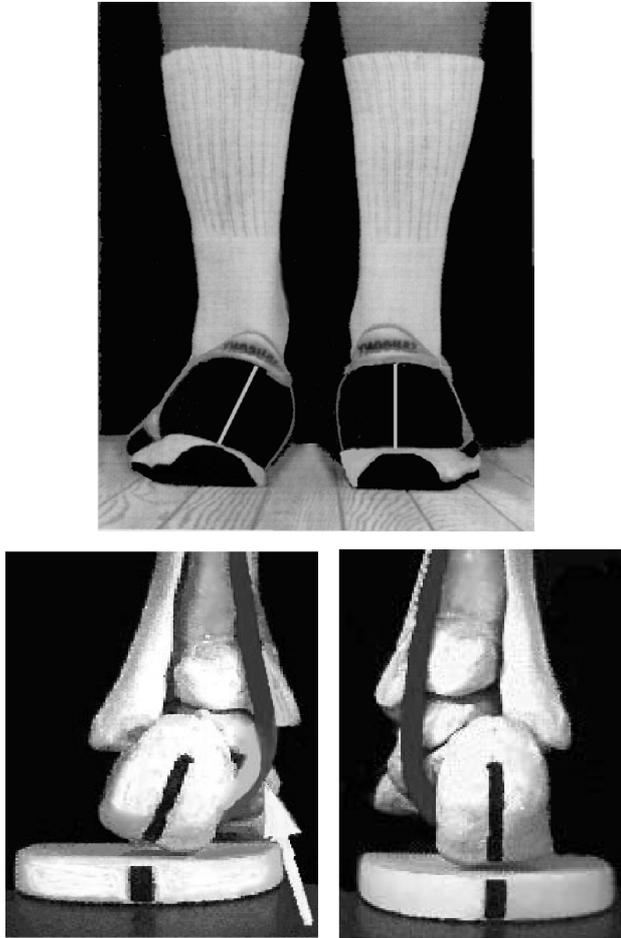


Fig. 8 The neurovascular network sits posteriorly and inferiorly to the medial malleolus. Hyperpronation associated with PME >20 mm (see left foot) can compress this network, significantly reducing blood flow and innervation to the bottom of the foot (see bottom, left diagram).

ILA is present by age 2. By age 30 months, maximal inner longitudinal arching is attained, the apex corresponding to the navicular tuberosity (Blais & Green 1956). As the ILA takes on its adult contour and the navicular bone ossifies, PME becomes more visible. However, measuring PME in a child less than 4 years of age is prone to error because the navicular bone has not yet ossified.

In the adult foot (aged 4 and over), PME values between 10 mm and 25 mm are pathognomic of RFS. Flexible arches (higher arch

sitting than standing) and flexible flatfeet (arch sitting, no arch standing) are functional compensations commonly associated with RFS. The supinatory 'strike', in which the body's weight is carried on the outside margins of the heel, is another common compensation associated with RFS. Visual inspection of these shoes reveals an excessive wear pattern on the outside margins of the heels. When dealing with RFS, measuring forefoot varum across the entire sole (metatarsals 1–5) is a misdirected clinical assessment, since talar

supinatus only affects the 1st metatarsal.

A preliminary investigation correlating PME values to compensatory patterns in 37 infants, ages 2–4, is undertaken at the Bellevue Foot and Ankle Center in Bellevue Washington (1988–1994). The following factors are measured: foot type (flexible arches or flexible flatfeet), position of feet (pigeon-toed, straight or out-toed), heel strike (inside or outside), and PME values. The results suggest that infants (under age 4) with PME values >20 mm tend to adduct (pigeon-toe). As children they are typically inside heel strikers and flat-footed (flexible flat-feet). Infants with 11–19 mm PME tend to abduct (out toe). As children they are outside heel strikers and have flexible arches.

The above findings provide a possible pattern of compensations associated with various PME ranges. Infants with higher PME values (>20 mm) tend to instinctively reduce (adapt to) their dynamic hyperpronation by turning their feet inward. Infants exhibiting lower PME values (11–19 mm) tend to either 'fall into' a mild to moderate hyperpronation pattern (feet turned outward), or adapt by walking on the outsides of their feet (feet straight forward). In both cases, as children they appear to have flexible arches. The above observations are insightful but not definitive (26 of the 37 children follow these patterns). This study needs to be repeated using larger sample sizes over a longer period of time.

Clinical data compiled at GRD BioTech Inc in Seattle Washington (2001) collaborates earlier studies linking higher PME values to RFS (Rothbart et al. 1992, Cummings 1994, Schneider et al. 1995, Rothbart & Hansen 1995). Three hundred and seventeen patients are measured with microwedges (Fig. 7).

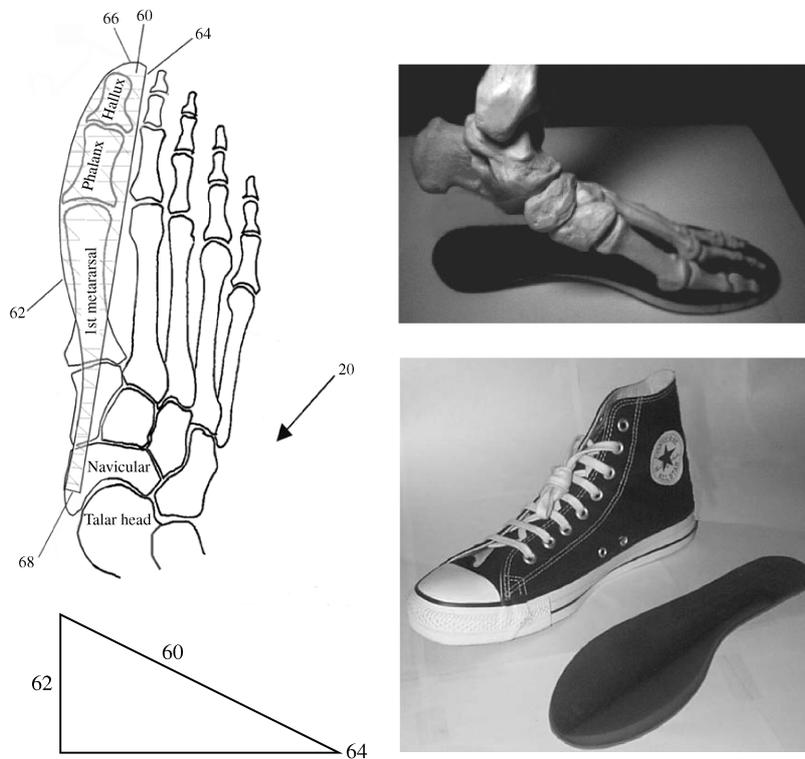


Fig. 9 Medial column system. Tactile feedback loop extending from the navicular to the hallux. The system is sloped (60) medial to lateral. The vertical dimensioning discussed in the paper is represented by line (62), which extends along the medial border of the foot. Typically arch supports are not incorporated into the medial column system. Visual gait studies on 317 clients delineate: 30% tactile feedback results in approximately 70% decrease in dynamic hyperpronation (the 30–70 rule). USPTO #6,092,314 Sheet 4, Figure 5. Adapted and reproduced with permission from GRD BioTech Inc., 2000.

Three hundred and six (96.5%) demonstrate an RFS with a mean PME of 16 mm (distance [freeway space] between the 1st metatarsal and ground, subtalar joint in neutral [joint congruity] position). Of these, 271 (88.5%) have flexible arches (mean PME of 14 mm), and 35 (11.5%) have flexible flat-feet (mean PME of 24 mm). Ten (3.1%) demonstrate a non-RFS (mean PME of 6 mm). 1 (0.3%) has a mild Cfd (PME of 31 mm).

The typical pronated posture

PME (> 10 mm) significantly forces the walking foot to roll inward, forward and downward (typically left foot > right foot) until the 1st metatarsal reaches the ground

(Rothbart & Esterbrook 1988, Rothbart et al. 1995, Schneider 1995, Filner 1996, Liley 1996). This shifts the body's center of gravity forward and downward, which in turn, pulls the innominates forward and downward (typically left > right). The pelvis is unlevelled, resulting in a functional leg length discrepancy (left longer than right). As these displacements cascade up the axial framework, scoliotic and kyphotic curves are exaggerated. The thoracic cage twists (usually counterclockwise). The shoulders protract (left > right) The right shoulder drops. Cranially, the maxilla moves anteriorly relative to the mandible resulting in an overjet bite. This gravity-induced skeletal 'collapse' is termed

BioImpllosion (Rothbart et al. 1992, Rothbart & Yerratt 1994, Schneider 1995, Petersen et al. 1995, Filner 1996, Liley 1996), which over time can initiate strain and trigger point patterns, foot to jaw (Rothbart et al. 1992, Rothbart & Hansen 1995, Schneider 1995, Petersen 1995, Filner 1996, Liley 1996).*

Johnson and Cross (1990) describe a common compensatory pattern (CCP) that is very similar to the BioImploded posture outlined above. Johnson and Cross link posture to torsions within the pelvis. Rothbart et al. (1992) link posture to torsions (hyperpronation) within the feet. Zink & Lawson (1979) describe a disparent (atypical) CCP. Interesting enough, this disparent CCP closely parallels the Bio-Imploded posture resulting from the less common hyperpronation pattern of right > left.

Hyperpronation associated with PME > 20 mm can mechanically compress the posterior tibial vessels (nerve, artery and vein) as they enter the foot behind the medial malleolus. This is quickly determined by taking standing PT pulses: foot neutral and then pronated (Fig. 8).

From clinical observations, RFS appears to be a dominant, single autosomal Mendelian characteristic. This would explain the familial diathesis and the inordinate rate of expansion in the genetic pool (Garbalosa et al. 1994). Harris and Beath (1949) evaluate the foot structure of 3619 Canadian men. Their study suggests a 40% incidence of Morton's foot structure (short 1st metatarsal). A more recent investigation, presented at the Annual Conference of the American Academy of Pain Management (Rothbart 1995), suggests a 95%

*For example, chronic shoulder protraction can lead to a functional thoracic outlet syndrome.

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Primus metatarsus elevatus table

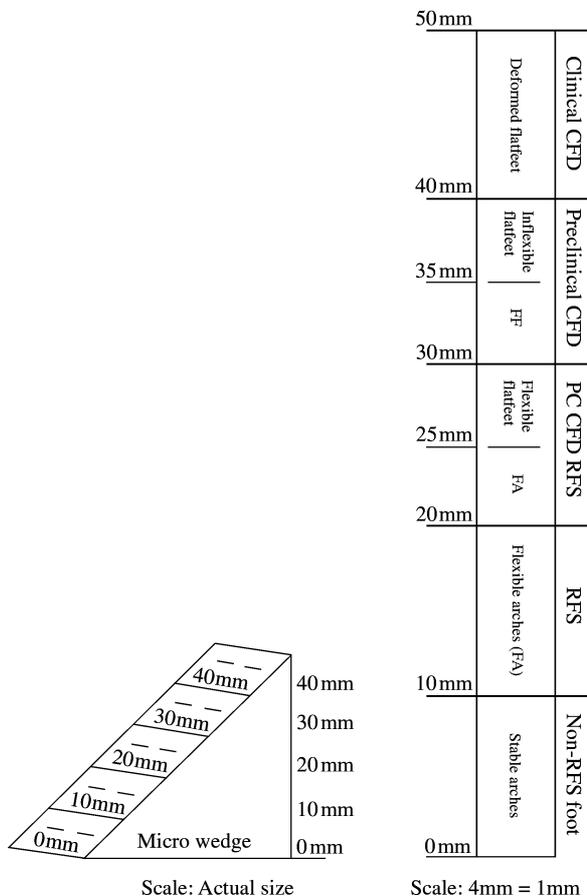


Fig. 10 Primus metatarsus elevatus table. A linear correlation is seen between PME values and foot structure. Low PME values ($<10\text{ mm} \pm 1\text{--}2\text{ mm}$) are associated with a non-RFS. In the absence of significant soft tissue or cranial adaptations: midrange PME values ($10\text{--}25\text{ mm} \pm 1\text{--}2\text{ mm}$) are associated with RFS, ranging from flexible arches ($10\text{--}19\text{ mm} \pm 1\text{--}2\text{ mm}$) to flexible flatfeet ($25\text{--}35\text{ mm} \pm 1\text{--}2\text{ mm}$). High PME values ($>40\text{ mm}$) are associated with Clubfoot deformities with overt arch deformation.

incidence of Morton/Rothbart's foot structure (short and elevated 1st metatarsal).

Stabilizing RFS

Heel wedges and arch supports

Calcaneal wedging decreases standing hyper-pronation. Calcaneal wedging *does not* decrease walking hyperpronation generated from the elevated 1st metatarsal. In fact, inverting the whole foot in this fashion can increase the relative elevation of the 1st metatarsal to the ground, which in turn can increase

the hyperpronation generated at heel-lift. In a similar fashion, arch supports decrease midstance hyperpronation, but are ineffective as the ball of the foot engages in weight bearing. Paradoxically, arch supports affect feet like immobilization casts affect muscles: function is improved at the price of muscle strength. In time, these same feet become weaker/more pronated (when barefooted) than they were prior to arch support therapy. For this reason, the author rarely uses heel wedges in RFF, and only uses arch supports in feet that are functionally flat.

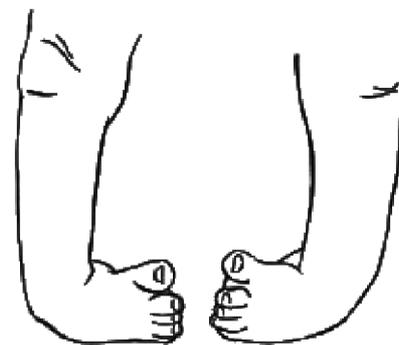


Fig. 11 The Clubfoot deformity.

Medial column systems

Medial column systems effectively reduce dynamic hyperpronation associated with RFS. The effect of these systems extend from the navicular, medial cuneiform, 1st metatarsal bone, to the proximal phalanx and hallux (Fig. 9). With each step, a tactile feedback loop is triggered that auto corrects the hyperpronation being initiated by the PME. The suggested rule of thumb is: 30% tactile = 70% improvement (the 30–70 rule is observational, based on empirical data derived through gait evaluation of 317 patients at the GRD BioTech facility, 1996–1998, and hence not meant to be definitive or all inclusive). For example, a 6 mm medial column system (Fig. 9[62]) under a foot measuring 20 mm PME (assuming no significant hypertonicity patterns or cranial deformations) tends to decrease the observable hyperpronation by approximately 70%. Via proprioception, this system provides feedback to the big toe (proximal phalanx and hallux) and 1st metatarsal. All the other weight bearing structures proximal to the big toe and 1st metatarsal (ankle, knee, pelvis, spine, neck, head and jaw) tend to spontaneously correct themselves around this change. The body's center of gravity shifts

posteriorly. The posture is *visually* more vertical. The inner longitudinal arch is not supported in feet with flexible arches. (Arch supports are used in flatfeet to facilitate the transfer of vector forces across the ILA). The heel is neither cupped nor wedged.

Tactile feedback systems are based on the observation that small repetitive stimuli bring about significant changes. Interesting enough, in terms of foot mechanics, this occurs through kinesthetic reposturing. The foot-brain connection recognizes this proprioceptive input as innately correct. The foot is reminded where it should be (not here, but over there) and automatically makes the adjustment. With each step, the foot becomes stronger, the posture straighter. Hyperpronation is reduced. And not surprisingly, as the soft tissue and cranial adaptations are addressed, the tactile input in the medial column system may require recalibration (adjustment). An unexpected outcome using foot tactile systems is the observation that hypertonic muscles can become *disassociated* from Morton/Rothbart's foot structure. That is, these short and tight muscles evolve into self-perpetuating loops. Their associated pain referral patterns prove intractable to foot therapy alone. This underscores the importance of concurrent foot and soft tissue therapy when dealing with chronic pain issues.

The medial column foot system is used as a proprioceptive stimulator. It is dimensioned to partially fill-in the 'freeway space' that exists between the 1st metatarsal/big toe and ground (Fig. 6). If this system is dimensioned so that it completely fills in the 'freeway space', it becomes a supportive device. Such devices over a period of time weaken structure and should not be used under the RFS. Using a medial

column foot system in a *non-RFS* places a disruptive upward load under the 1st metatarsal head. This can dramatically limit the range of dorsiflexion within the 1st metatarsal-phalangeal articulation and lead to a potential functional hallux limitus.

Summation

The foetal development of the lower limb bud, and specifically the footplate, is reviewed. Clinical studies describe the impact talar and calcaneal supinatus have on the medial column of the foot: incomplete unwinding of the talar head results in the Morton/Rothbart foot structure; incomplete unwinding of the calcaneus results in the Clubfoot deformity (Fig. 11).

Zitzlesperger (1960) and Elftman's (1960) foot models demonstrate an inverse relationship between pronation and arch stability: as pronation increases, arches flatten. Clinical data from GRD BioTech (2001) demonstrates a similar inverse relationship between PME (elevation of the 1st metatarsal and big toe) and arch stability: as PME increases, arch stability decreases. PME values less than 10 mm correlate to stable arches (same arch height sitting or standing). PME values between 10 mm and 20 mm correlate to flexible arches (higher arch sitting than standing), 25 mm–30 mm to flexible flatfeet (arch sitting, no arch standing), 35 mm–40 mm to inflexible flatfeet (no arch sitting or standing), and >40 mm to structurally deformed feet (Fig. 11 – the Clubfoot deformity).

PME between 10 and 25 mm are associated with RFS, a foot in which the 1st metatarsal is short and structurally elevated relative to the lesser metatarsals. Rearfoot posts destabilize the RFS. Arch supports weaken the RFS.

And forefoot varum posts (Root et al. 1971) structurally strain the RFS.**

Published studies link PME to hyperpronation and hyperpronation to BioImplosion. Dimensioning medial column systems at 30% of the measured PME tend to decrease dynamic hyperpronation by $70\% \pm 10\%$. This in turn tends to reduce pelvic tilts by $50\% \pm 20\%$, shoulder protractions by $40\% \pm 20\%$ and forward head positions by $30\% \pm 20\%$. In the absence of any significant psychological or nutritional imbalances, hypertonic muscles become significantly more amendable to long-term resolution as posture becomes more vertical.

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**Only the 1st metatarsal is in elevatus in the RFS. Forefoot varum posts elevates metatarsals I–IV. The terms supinatus and varum have been used interchangeable in the literature. By convention, supinatus is used to describe a torsionally inverted relationship in the prenatal foot. Varum is used to describe the same torsional (structural) relationship in the postnatal foot.

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